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ABSTRACT

This paper describes the philosophy, implementation, and assessment of the Natural Sciences (NatSci) Program at the University of New Mexico which is designed to provide preservice elementary and middle school teachers with the understanding of science content and processes necessary to teach science confidently and competently in their future classrooms. The program's emphasis on small classes, concept-building, integration of sciences, diverse learning styles, and the use of constructivist teaching techniques appear to be successful in increasing students' comfort level in science. (WRM)

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The Natural Sciences Program at the University of New Mexico: Personalizing Science for Elementary Education Majors

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THE NATURAL SCIENCES PROGRAM AT THE UNIVERSITY OF NEW MEXICO: PERSONALIZING SCIENCE FOR ELEMENTARY EDUCATION MAJORS

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The mission of the Natural Sciences (NatSci) Program at the University of New Mexico (UNM) is to provide pre-service elementary and middle school teachers with the understanding of science content and processes necessary to teach science confidently and competently in their future classrooms. This is accomplished by addressing diverse learning styles and assisting students to build scientific concepts in personally meaningful ways through modeling of effective teaching techniques. Because they will be teaching children, whose natural curiosity causes them to question the workings of the world around them, our students must have the skills to help their future students find the answers to their questions. They must be able to guide children through investigations and observations and aid in understanding the natural world.

Program Philosophy

All instructors in our program are dedicated to the NatSci philosophy that says "Because our students will be elementary and middle school teachers, they will have the most important job in the world. That makes our students the most important people on campus." We assume that our students are intelligent and have the ability to comprehend science. However, a majority of our students are science- and math-phobic. We must overcome their resistance to science by demonstrating the utility of scientific knowledge, and more importantly, scientific processes. We do not weed out the unwilling, but attempt to convert students who are open to new ideas and willing, even eager, to find the answers to their own questions. In many cases, this requires that we prompt them to *ask* questions in the first place.

Our program is housed within the Department of Earth and Planetary Sciences, in the College of Arts and Sciences. We teach science content, not science methods. Our students take their science methods class once they are accepted into the College of Education (CoE), either just

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before student teaching or while they're student teaching. What they do get from us is the science content background, the inquiry and research skills they need to understand what's going on in their science methods course, and the confidence to investigate science topics on their own. We differ from standard introductory-level, single-discipline science classes in that we provide an experience that is specifically tailored to the needs of future teachers.

Course Sequence

The NatSci sequence consists of three semesters, required of all elementary education majors at our institution. In designing our curricula, we have struggled to strike the difficult balance between covering the basics in a variety of sciences, while investigating them deeply enough that our students truly understand them. We would like to at least introduce the major points of each major science area, so that our students will know where to look up the answers to their future students' questions. Yet, if we employ a broad, shallow-level introduction to all of these sciences, our students won't come to comprehend any of them in sufficient depth that they'll be able to teach them.

To better establish what content should be taught in every section of our three courses, instructors of the Nat Sci program spent last summer in a collaborative effort with Albuquerque Public School master and novice teachers, and some of our students, funded by the New Mexico Collaborative for Excellence in Teacher Preparation (NM-CETP). This effort also delineated methodology recommendations to be used in the three courses and formalized our course requirements. While the Nat Sci program feels strongly about preserving instructor autonomy, these guidelines result in better consistency among the different sections of our course.

Course content builds from one semester to next. Nat Sci 261 (Physical Science) is a prerequisite for Nat Sci 262 (Life Science), which is a prerequisite for Nat Sci 263 (Environmental Science). Integrated, cross-disciplinary issues (e.g., waste disposal and global warming) are revisited and reinforced throughout all three semesters.

Commonalities Among the Three Courses

Each class meets 5 hours a week, comparable to a lecture + lab course, but the lecture and

lab components of our courses are integrated. Each section of each class varies greatly in its collective prior knowledge. Constructivist learning requires that we assess quickly what each of our students knows, so that we can help them build on that, or rebuild after confronting previous misconceptions. Our classes are inquiry-based, activity-based and issues-based. Instructors guide students to develop their own understandings on a personal level. This personal approach is facilitated by relatively small class sizes (24 students maximum).

We utilize the Benchmarks for Science Literacy (AAAS, 1993) and National Science Education Standards (NRC, 1996) extensively in all three classes. These guidelines demonstrate to the students what their students will be expected to learn at different age levels for each of the scientific subjects we teach, as well as ways the different sciences are integrated with each other, with math and with technology. Use of these documents teaches our students how to make informed decisions regarding what and how to teach in their future careers. The standards also provide NatSci instructors with an appropriate answer to the often-asked question "Why do we have to know this?".

We utilize peer instruction methodology extensively. Students work in groups to answer questions (in the first semester, mostly questions posed by the instructor; in the third semester, mostly questions developed by the students themselves; and a fairly even mix of the two in the second semester). When one or two students in a group who "get" a concept explain it to others, the explainers clarify it for themselves, often discovering even more about the concept while doing the explaining, and the listeners receive the benefit of hearing how the explainers figured it out. In addition, NatSci instructors listening in on these discussion learn better how our students process information.

All students also participate in field trips. Some field trips meet within class time and others take place on Saturdays. The trips are designed to enhance student understanding of class work by demonstrating its applicability to the world around them. These field trips serve as an introduction to the locally available resources our students will use in their future careers. In all three of our courses, our students gain experience working with children in real classrooms.

A disturbing number of our students have never written reports before. All of our students write reports about their field trips and classroom experiences. As part of each report, they research science education standards and include those that touch upon their experiences. They cite the standards and benchmarks, and any other references they use in writing their reports. We also set aside some class time for students to share with others what they did/saw/learned on field trips or in their classroom experiences. This allows the students to process their experience through talking to others about it, which helps them to prepare for writing their reports. All three classes also develop student use of technology, through use of email assignments, Internet searches, designing of student web pages, etc.

Nat Sci 261: Physical Science

The first semester covers physics, astronomy and geology. A large percentage of our first-semester students have recently come from a structured high school environment, are used to being spoon-fed information and are reasonably good at memorizing and regurgitating on exams. They tend to work best in a structured environment initially: reading textual materials before class, short lectures in class to clarify target concepts and vocabulary, then hands-on laboratory exercises. Over the course of the first semester, we gradually wean them away from structure by encouraging them to ask questions and to perform scientific inquiries to help them find the answers.

There is a Saturday geology field trip associated with this class. The Albuquerque area is a fabulous outdoor classroom for a lot of different science areas, especially geology. Nat Sci 261 students are also required to attend a "star party". Every Friday night during the school year, the UNM Astronomy Club sets up a multitude of telescopes, and numerous professional and amateur astronomers share their knowledge and enthusiasm with our students. This assignment generally meets with a lot of grumbling at first. Our students do *not* want to give up a Friday night. However, once they go to one of these parties, we get almost unanimous conversion. Our students discover the joy of exploring the night sky and are eager to share this experience with their future students.

A very important part of the student's grade is the in-classroom experience. In 261, students find or design a lesson plan for an activity that is geology, physics or astronomy-related. They practice their activities with each other in our classrooms, and provide each other with feedback, then go to a K-8 classroom and present the demonstrations. The classrooms are split into groups that cycle through all the demos. This committee arrangement allows our students to present their demos a number of times.

We also assign a number of email projects. While some of our students are well versed in the use of computers, a majority of them have not used email, the Internet, CD-ROMs or other computer resources. Our email assignments introduce the students to these resources. In addition to the research students need to do for their science demonstration, they have one more small research project on some body in the solar system.

Nat Sci 262: Life Science

In our second semester, chemistry is integrated with biology topics. We encourage increasingly more independent thought, and require students to complete some research on their own and present it to the class, then to schoolchildren. As we wean our students away from the structured style of the first semester and direct them toward more independent work, students keep journals of what they learn from their reading and in-class activities. These journals take the place of the daily homework and exercise sheets required in the first semester. The journals are collected and reviewed by the instructors periodically, so this feedback is not as constant as it was in 261. This process places more of the responsibility for learning on the students.

In 262, the required field trips are: a) a Saturday group visit to the Rio Grande Nature Center to study biological diversity, biological classification and ecological relationships between organisms; and b) an independent, outside-of-class-time judging of a science fair. Students also complete two important research projects. One is to research a particular organ system, write a report about it, and do a short presentation in class. The other is the construction of a giant cell. Each student researches a cell organelle, makes a model of it to fit into a giant cell model built by the class. The giant cell is constructed of a huge sheet of plastic (about 7 X 10 meters), folded

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over on itself, and blown up on one corner by a box fan, leaving another corner open to use as a door. Students enter the cell and put their organelles in place, and explain the function of the organelle to the class. After the test run in our classrooms, they show the whole cell to an upper elementary or middle school classroom.

Nat Sci 263: Environmental Science

In our third semester, physical and life sciences are integrated. By this time, students are generally willing and able to be self-driven. The depth and focus of their questions, and their innovative attempts at solving their problems demonstrates this. In this third semester, students are able to integrate what they have learned into a coherent world view. This is the most interesting class for most of our students and the most fun to teach.

These students take a number of in- and out-of-class field trips. For example, we go to the UNM nuclear reactor, the landfill, and the Albuquerque Water Treatment Center (aka the sewage plant). Students also participate in a science curriculum program such as Project Wild, Project Wet, or Project Learning Tree. At these training sessions, they learn not only content and teaching methods, they also learn that these sorts of training sessions exist! Many students, having completed one of these sessions, want to go to all of the others.

The classroom experience for 263 students takes place at the Sandia Mountain Natural History Center (SMNHC), which is run jointly by Albuquerque Public Schools (APS) and the New Mexico Museum of Natural History. Every fifth grade student in the APS system, and many others from surrounding school districts, spend one school day at the center. Our students spend the day with one of the student groups. They join these students on a hike and participate in environmental learning activities throughout the day. In a typical group, there may be 16-20 kids, their teacher, one or two parents and the SMNHC teacher. When our students are there too, that increases the adult-to-kid ratio. I've had great feedback from the SMNHC staff, telling us that just having an extra adult to show an interest in what the children are doing, finding, discovering, enriches the experience for the children enormously.

They also do a substantial research project that requires them to synthesize what they've learned in all three semesters. The main inquiry-based project in 263 is to research an issue, write an outline for a classroom discussion, provide their classmates with the reading materials they need to prepare for discussion of the issue, and then lead a seminar-style discussion of the issue in class. All students evaluate the others' discussions and their own discussions. Examples of issues that are covered range from: global warming to human population growth and control to recycling. Each of these issues can be found in the daily news and really bring home the importance of science in our students' every day lives. They are also interrelated. For example, one group may cover urban planning, relating it back to what another team said about paving reducing the amount of infiltration into the aquifer, thereby reducing local water supply, and to another team's discussion of energy conservation though carpooling and public transportation. Students learn about the costs and benefits of every day choices and decisions, and the importance of making informed decisions. They become even more convinced of the importance of education in assuring that we have a world we want to live in in the future.

In this course, students see how important science is to so many of today's issues. They see how all of the sciences they have learned interrelate and make up complete, coherent pictures of how the world works as a whole. Students leave this class with a deeper than ever understanding of science concepts, science processes, and most importantly, they leave knowing that they, as teachers, have the power to make a real difference in the world. They know that the solutions to the vast majority of today's problems lie in education, and the solutions to environmental problems lie in understanding science.

Assessment

At this time, most of the feedback on our program is qualitative and anecdotal. We have always given our students instructor- and course evaluations at the end of each semester. These provide individual instructors with the information they need to improve things for the following semesters. We have not had time to look at the results of these evaluations for the program as a whole, but we will be doing so in the near future.

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We have recently designed and tested a more quantitative assessment. This survey instrument will be completed by all students upon entry to the program in 261, and again upon completion of the program at the end of 263. The survey includes demographic and science/math background questions. The bulk of the survey consists of very basic science content questions, about 20 questions for each course. Testing what they know upon entry to the program and what they learn while taking our classes will allow us to quantitatively evaluate our program. In addition to the pre- and post-assessments, we will be embedding some questions that test for the same content in midterms and finals within the course in which the individual content material is taught. Student responses to each of the questions at the pre-assessment, embedded, and post-assessment steps will be tracked. We also plan to distribute the surveys again to our past students, to see how well our material is retained a couple of years after completion of our program. We recognize, however, that those data are likely to be skewed in our favor, because the students most likely to respond to our surveys are the ones who learned the most, and are the most interested in science.

Preliminary Results

Upon entry to the program, the majority of our students do not want to take science. They had a little science in high school and they didn't like it. It was confusing, boring, or too nerdy. They have no current interest in science at all. Most view science as a collection of data to be memorized, regurgitated on exams and then forgotten. They think science is something only a few, really brilliant, often really boring, detail-minded, stodgy, European men wearing lab coats can do. They don't think of science as fun, creative, and interesting. They don't think of it as comprehensible or do-able by everyone. We consider it our job to change these attitudes over the three semesters we have them. Some quotes from the free-response portion of the beginning of last semester's survey of entering Nat Sci 261 students are:

> I hate science and am only taking this class because I have to.
> I don't have to learn science because I'm only going to teach 1st grade.
> I don't like science, but realize I'll have to teach it, so I have to learn it.

At the end of the semester the same students were saying:

> In this class, I learned that science can be fun, and even I can do it.
> Before this class I hated science, but because of this class, I've come to enjoy it.

I am actually excited to teach science and I never thought I would.

At the end of Nat Sci 263, some student quotes are:

I never knew science could be so fun and interesting!
I like this program because it is designed for teachers and it gave me what I need to succeed."
I look forward to using what I learned here in my classes.

However, our classes are *not* all fun and games. We could gee-whiz them to death with fun activities and demos, thereby changing their attitudes about science, but without providing them with any solid science content. Some sample content questions from our progress surveys, along with the percentage of students getting the question correct (at the beginning and end of the semester), are shown in Table 1:

Plans for the Future

In addition to gathering and tracking the quantitative results of our progress survey, we are also expanding and improving the resource base available to our instructors and students. Unfortunately, we have a pretty high instructor turnover rate, so we have established an ever-expanding file system to which instructors add new materials, ideas, activities, exercises, background material, etc for each of the topics we teach. These files allow new instructors to quickly learn from the experiences of past instructors. Although no regular faculty teach the NatSci classes, the instructors of these courses are professionals with a minimum of a M.S. degree in a pertinent area of science, and many are Ph.D.'s. Most importantly, NatSci instructors have a deep commitment to a pedagogical style that is relevant to our students as future educators.

Another thing that may significantly shape the future of the program is the soild realization reached by most of us this past semester that the targets established during last summer's curriculum refinement effort are still too broad to provide adequate coverage of all the target areas. It is not possible to teach all of the science our students need to know in only three semesters. A new approach allowing students to determine content is being tested this semester. Our students' first homework assignment will be to rank the NM science education standards and benchmarks applicable to the class in terms of importance/interest. Our students will see what will be required

Table 1
Sample Content Questions from Natural Science Program Progress Survey
Beginning and End of Fall, 1998 Semester

Course	Sample Survey Question	Percent Correct August, 1998	Percent Correct December, 1998
NS 261	You have a refrigerator in a perfectly sealed 75°F room and nothing (including heat) can get in or out of the room. You open the refrigerator door, set the refrigerator thermostat to 50°F, and leave the refrigerator door open. The refrigerator starts working. What happens to the temperature of the room? A. It goes up. B. It goes down to 50°F. C. It goes down, but not all the way to 50°F. D. It doesn't change. E. I have no idea.	17	78
NS 262	In mammals, oxygen is carried to the body tissue by means of the: A. digestive system. B. respiratory system. C. circulatory system. D. nervous system. E. I have no idea.	44	92
NS 263	Greenhouse gases: A. are gases released by plants during photosynthesis. B. are only artificial pollutants accumulated in recent times. C. are located just outside of the Earth's atmosphere. D. are substances in the Earth's atmosphere that absorb infrared radiation. E. I have no idea.	9	85

of them as teachers, and tell us what they are most interested in learning. This will increase the students' sense of responsibility for their own learning, and tell us what to focus on. While focusing on the areas the students choose, we will model the inquiry processes and teach the inquiry skills they will need to learn on their own the material we cannot cover in class. By doing this we will emphasize depth in favor of breadth. In order to teach science successfully, our students will need to know the topics they teach thoroughly, and truly comprehend not just the facts about that area of science, but how we know what we know about it.

Summary

Our small classes, emphasis on concept-building, integration of sciences, attention to diverse learning styles, use of constructivist teaching techniques, and introductions of students into classrooms are ideally suited to the needs of our students. Although data are preliminary, pre-course surveys followed by post-program assessments indicate that our methods are successful in delivering the science content and process skills that our students need. In addition, student evaluations of courses and instructors indicate that our goal of increasing student comfort levels with science is also being met. The majority of our first-semester science-phobes are science enthusiasts by the time they complete the program!

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